Risø energy report 7

Future low carbon energy systems

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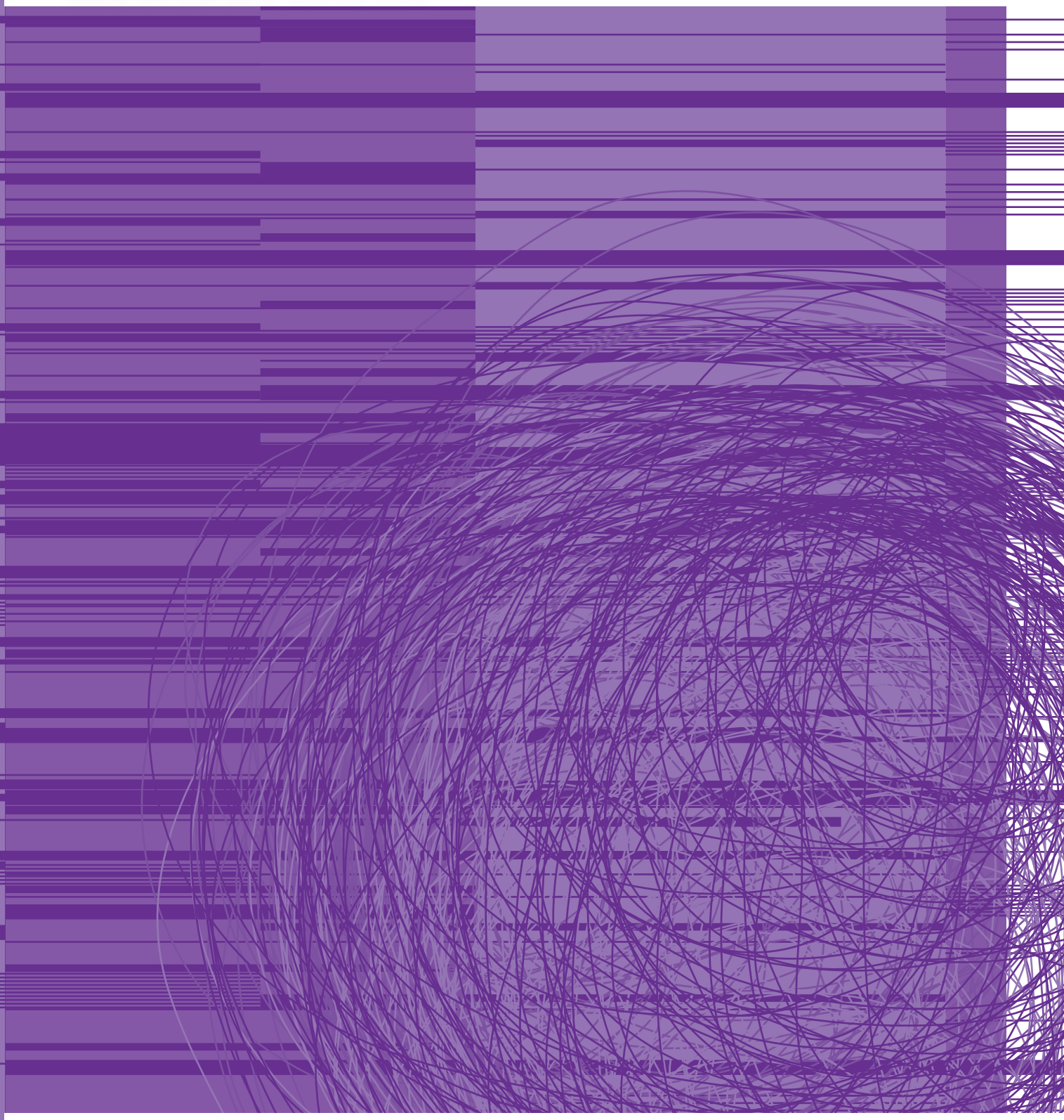

Risø DTU
National Laboratory for Sustainable Energy

Summary and recommendations

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Preface

This Risø Energy Report, the seventh of a series that began in 2002, takes as its point of reference the recommendations of the Intergovernmental Panel on Climate Change (IPCC) in 2007. The IPCC states that if anticipated climate change is to remain in the order of 2 to 3 degrees centigrade over the next century, the world's CO_2 emissions would have to peak within the next 10 – 15 years and ultimately be reduced to approximately 50% of their present level by the middle of the century.

The IPCC states further that this would be possible, provided that serious action is taken now. The different regions and countries of the world are in various states of development, and hence have different starting points for contributing to these reductions in CO_2 emissions.

This report presents state-of-the-art and development perspectives for energy supply technologies, new energy systems, end-use energy efficiency improvements and new policy measures. It also includes estimates of the CO_2 reduction potentials for different technologies. The technologies are characterized with regard to their ability to contribute either to ensuring a peak in CO_2 emissions within 10 – 15 years, or to long-term CO_2 reductions.

The report outlines the current and likely future composition of energy systems in Denmark, and examines three groups of countries: i) Europe and the other OECD member nations; ii) large and rapidly growing developing economies, notably India and China; iii) typical least developed countries, such as many African nations. The report emphasises how future energy developments and systems might be composed in these three country groupings, and to what extent the different technologies might contribute.

The report addresses the need for research and demonstration together with market incentives, and policy measures with focus on initiatives that can promote the development towards CO_2 reductions. Specifically, the report identifies system options and technology mixes that can lead to the emissions peak in 2020 and 50% reduction in the long run, at the Danish and global level.

The report is based on the latest research results from Risø DTU, together with available international literature and reports.

Summary and recommendations

The global energy scene is currently dominated by two overriding concerns that strongly affect decisions on energy development priorities:

1. Security of supply
2. Climate change

This is especially true for industrialised countries and the more rapidly developing economies. At the same time, many developing countries face really basic energy development constraints that give a quite different meaning to the concept of energy security.

Climate change is widely recognised as the major environmental problem facing the world. The IPCC Fourth Assessment Report states clearly that it is no longer relevant to discuss whether the climate is changing.

Many countries concerned about energy security and climate change have set ambitious targets for renewable energy. Renewable energy worldwide is still dominated by the "old" renewables: hydropower and traditional biomass that supply respectively 6% and 9% of global primary energy demand. Only around 2% of the world's primary energy is currently provided by "new" renewable sources such as wind, photovoltaics and mini- and micro-hydro.

The introduction of more renewables needs to be managed in a way that ensures the same security of supply and economic performance as the energy systems of today, while delivering better environmental performance, especially with regard to CO_2 emissions, and less dependence on fossil fuels.

Different solutions for different regions

The countries of the OECD strongly influence the development of energy demand and new energy supply opportunities. The OECD countries are amongst the fastest in developing new renewable technologies, but they are at the same time becoming increasingly dependent on imported fossil fuels.

OECD countries' growth in energy demand will be much lower than in the rest of the world. The OECD's share of world primary energy is as a consequence expected to decline from almost 49% in 2005 to 34% in 2050, provided that energy and environmental concerns receive the political attention they deserve.

Fossil fuels are currently the dominating energy supply in OECD-countries. Worldwide, the International Energy Agency (IEA) estimates the share of fossil fuels to be approximately 50% in 2050.

Rapidly-developing countries like China and India are important in shaping world trends in economic and energy development and how they develop will affect the possibilities for solving the climate problem. With their enormous new investments in energy infrastructure over the coming decades, these countries have a rare window of opportunity to move towards low-carbon development and low-cost greenhouse gas (GHG) emissions reduction.

With their large territories and population bases, high economic growth and rising living standards, China and India are seeing strong growth in freight and passenger transport. They are already home to several of the world's mega-cities, while new cities are being created and others continue to expand as a result of ongoing massive urbanisation. In view of the lack of oil reserves in these countries, clean vehicles and public transport will be the key technologies for tackling the four-fold challenge of oil supply, local air pollution, traffic congestion and GHG emissions.

These countries generally use energy less efficiently than the OECD countries. China's energy conversion and utilisation efficiency, for instance, is around 25% lower than in industrialised countries. In 2000, energy consumption per physical unit of industrial production in China was around 40% higher than that in advanced developed countries.

Compared to other parts of the world, the rate of economic development in the least developed regions like sub-Saharan Africa has been extremely low over the last 45 years.

Climate change is not in itself a priority driver in the energy policies of the least developed countries, since per-capita energy consumption and CO_2 emissions are low. However, in many of these countries the first option for new energy supply is fossil fuel, and there will thus be increasing opportunities for cooperation with industrialised countries. These opportunities include carbon financing and investment in low-emission energy technologies, including clean coal, gas, biomass and other renewables, where appropriate.

Future energy development in the least developed countries will depend strongly on economic growth. This in itself will rely on, among other things, the establishment of an enabling environment in terms of energy infrastructure.

Large-scale infrastructure investments need to go hand in hand with the development of decentralised energy systems at the community level. In the first few years these are expected to be based on small-scale diesel systems, but from 2010 to 2020 they will increasingly be established as hybrid systems based on small-scale hydro, wind or photovoltaics (PV), depending on available resources of wind and hydro. For these systems, diesel may increasingly be substituted with biofuels, provided that biofuels are not conflicting with food production.

Regional trends and development potential

Although climate change is a common global challenge, the different regions of the world have quite different economic, technological and political preconditions for emissions reduction strategies.

The EU has taken the global political lead with its ambitious targets for GHG reductions and an increased proportion of renewable energy.

The USA has focused much more on domestic energy security; its rapid increase in corn-based bioethanol is a clear example of policy that addresses energy security but contributes very little to GHG reductions or longer-term supply stability.

China and India share a diversified approach that reflects their rapidly-growing economies and associated expansion in energy demand. This includes ambitious targets for renewable energy and energy efficiency, increased domestic production, and collaboration with a large and diverse group of oil- and gas-producing countries, notably in Africa.

While the impacts of climate change will be felt in every region of the world, it is clear that poorer developing countries and tropical islands are particularly vulnerable. With weak institutions and limited human and financial resources, such countries have limited ability to cope with or adapt to climate change, and they will require strong international support.

The focus on climate and security has reduced the political attention given by most potential donors to energy access in the poorest countries.

Finding a global energy development path that addresses both security of supply and climate change is a major challenge that requires coordinated action from all countries.

CO_2 reduction strategies in Denmark

Denmark has the potential for large CO_2 reductions at low additional cost. This will require a mix of measures covering both energy demand and energy supply, the most important of which are:

- Energy savings with annual reductions of 1–3% in energy consumption
- More efficient conventional vehicles and plug-in hybrid vehicles
- Increasing the share of wind power, in particular offshore
- Increased use of biomass for building heating and process heat in industry and CHP plants
- Development of second-generation biofuel technology for transport

- Energy infrastructure development, including flexibility
- New and improved market measures

Global CO_2 reduction possibilities

In the shorter term (up to 2030), the main contributors to GHG mitigation are demand-side measures, efficiency improvements in the energy sector, and reductions in emissions of GHGs other than CO_2. Many short-term energy efficiency measures even have negative abatement costs.

In the longer term, efficiency can be improved in many ways. The multitude of options creates many opportunities for GHG reduction, as well as challenges in identifying the winning technologies.

Climate change is a long-term problem, and early action is important if we are to remain on a lower emissions trajectory that will allow flexibility in the future. Technologies that are important for short-term mitigation are not necessarily sufficient for the long term. A diversified portfolio of choices is needed, and this will require R&D investment over long periods before we reach the ultimate objective.

Recommendations

Denmark could profit from being in the front with developing a low carbon energy system that could increase independence in relation to energy supply and give a competitive advantage in new energy technologies.

There is a need to reinforce Denmark's power transmission grid, in part to meet the needs of future offshore wind power plants. Electricity storage is an important element in reinforcing the grid. Another pressing matter is the establishment of an intelligent grid with two-way communication to facilitate the integration of more wind power.

Large-scale integration of renewable energy in Europe requires a pan-European transmission network to allow effective cross-border power trading and provide mutual support for security and quality of supply.

International collaboration and support for the introduction of new, more efficient, energy technologies for countries like China and India will be important.

It is important to expand the use of instruments like the Clean Development Mechanism (CDM) to further the development and implementation of low-carbon energy systems in developing countries.

Stimulating cooperation between existing regional power pools in developing countries will be essential in exploiting large but regionally-diverse resources such as hydro, coal and natural gas, needed to provide electricity to meet increasing urban demand. Rural electrification will depend on options for affordable grid based electricity.

Intensified research and demonstration for new energy technologies, particularly systems adapted to the specific needs of different regions of the world, and preferably in international collaboration, must be stimulated locally, regionally and globally.

Educating the next generation of energy specialists, engineers and energy policy makers worldwide is important to the development and use of new energy technologies at local, regional and global levels.

Initiatives are needed to raise industrial energy efficiency at local, regional and global levels.

The global building sector offers tremendous possibilities for saving energy, but incentives are needed to make this a reality.

Carbon capture and storage (CCS) could be an important medium-term option, allowing the world's large remaining reserves of fossil fuels to be used in an environmentally-benign manner. R&D and international cooperation in CCS should therefore be stimulated.

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Risø Energy Report Series

Risø Energy Report 1

New and emerging technologies: options for the future

All over the world, increasing energy consumption, liberalisation of energy markets and the need to take action on climate change are producing new challenges for the energy sector. At the same time there is increasing pressure for research, new technology and industrial products to be socially acceptable and to generate prosperity. The result is a complex and dynamic set of conditions affecting decisions on investment in research and new energy technology.

Edited by Hans Larsen and Leif Sønderberg Petersen
Risø National Laboratory, October 2002, 64 p.
ISBN 87–550–3082–3
Risø-R-1351(EN) (515 Kb)

Risø Energy Report 2

New and emerging bioenergy technologies

Three growing concerns – sustainability (particularly in the transport sector), security of energy supply and climate change – have combined to increase interest in bioenergy. This trend has been further encouraged by technological advances in biomass conversion and significant changes in energy markets. We even have a new term, "modern bioenergy", to cover those areas of bioenergy technology – traditional as well as emerging – which could expand the role of bioenergy.

Edited by Hans Larsen , Jens Kossmann and Leif Sønderberg Petersen
Risø National Laboratory, November 2003, 48 p.
ISBN 87–550–3262–1
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Interest in the hydrogen economy has grown rapidly in recent years. Countries with long traditions of activity in hydrogen research and development have now been joined by a large number of newcomers. The main reason for this surge of interest is that the hydrogen economy may be an answer to the two main challenges facing the world in the years to come: climate change and the need for security of energy supplies. Both these challenges require the development of new, highly-efficient energy technologies that are either carbon-neutral or low-carbon.

Edited by Hans Larsen , Robert Feidenhans'l and Leif Sønderberg Petersen
Risø National Laboratory, October 2004, 76 p.
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The coming decades will bring big changes in energy systems throughout the world. These systems are expected to change from central power plants producing electricity and sometimes heat for customers, to a combination of central units and a variety of distributed units such as renewable energy systems and fuel cells.

Edited by Hans Larsen and Leif Sønderberg Petersen
Risø National Laboratory, October 2005, 62 p.
ISBN 87–550–3474–8
Risø-R-1534(EN) (4 Mb)

Risø Energy Report 5

Renewable energy for power and transport

Global energy policy today is dominated by three concerns: security of supply, climate change, and energy for development and poverty alleviation. This is the starting point for Risø Energy Report 5, which addresses trends in renewable energy and gives an overview of the global forces that will transform our energy systems in the light of security of supply, climate change and economic growth. The report discusses the status of, and trends in, renewable energy technologies for broader applications in off-grid power production (and heat).

Edited by Hans Larsen and Leif Sønderberg Petersen
Risø National Laboratory, November 2006, 72 p.
ISBN 87–550–3515–9
Risø-R-1557(EN) (4 MB)

Risø Energy Report 6

Future options for energy technologies

Fossil fuels provide about 80% of global energy demand, and this will continue to be the situation for decades to come. In the European Community we are facing two major energy challenges. The first is sustainability, and the second is security of supply, since Europe is becoming more dependent on imported fuels. These challenges are the starting point for the present Risø Energy Report 6.

Edited by Hans Larsen and Leif Sønderberg Petersen
Risø National Laboratory, November 2007, 84 p.
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Risø-R-1621(EN) (2,5 MB)